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**EDGWOOD ARSENAL
TECHNICAL REPORT**

EATR 4377

CS IN WATER: EFFECTS ON HUMAN EYES

by

**Roy H. Rengstorff, MAJ, MSC
Millard M. Mershon, V.M.D.**

December 1959



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DEPARTMENT OF THE ARMY

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CS IN WATER: EFFECTS ON HUMAN EYES

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Experimental Medicine Department

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Task 1T061101A91A15

**DEPARTMENT OF THE ARMY
EDGEWOOD ARSENAL
Research Laboratories
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Edgewood Arsenal, Maryland 21010**

FOREWORD

The work described in this report was authorized under Task 1T061101A91A15, In-House Laboratory Independent Research - Edgewood (U). This work was started in July 1969 and completed in August 1969.

The volunteers in these tests were enlisted US Army personnel. These tests were governed by the principles, policies, and rules for medical volunteers as established in AR 70-25.

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DIGEST

This was a study of the effects of 0.1% and 0.25% o-chlorobenzylidene malononitrile (CS) in water with 0.5% polysorbate 20 when placed in the human eye. Each of the 16 subjects received one drop or a brief spray in one eye. They could not open their eyes for 10 to 67 seconds, and only after 35 to 135 seconds were they able to read 20/20 letters. The visual incapacitation appeared to be similar for both concentrations. Fluorescein staining of the cornea was assessed under ultraviolet light and with a slitlamp biomicroscope. It was concluded that concentrations of 0.1% and 0.25% CS in water with 0.5% polysorbate 20 that reach the eye in either a drop or a brief spray cause transient conjunctivitis but no corneal damage in man.

CS IN WATER: EFFECTS ON HUMAN EYES

I. INTRODUCTION.

Is a concentration of 0.25% o-chlorobenzylidene malononitrile (CS) in water with 0.5% polysorbate 20 safe in the human eye? The answer to that question is important if this mixture is to be used in riot-control situations. Animal studies by Owens and coworkers* showed that a 1.0% concentration caused no significant damage to rabbit or monkey eyes. Another study** showed negligible effects when over 500 ml of a 0.5% concentration was sprayed on rabbit eyes. The animal data demonstrated enough safety to predict little risk in testing small amounts on human eyes.

CS-water slurries had not been tested previously on human eyes, but they had been tested on human skin and caused delayed erythema when concentrations were 0.5% and higher.† The adverse skin effects appeared to preclude acceptance of 0.5% slurries as riot-control agents. This was the major consideration in our testing the lower concentration of 0.1% and, if there were no contraindications from those tests, 0.25%.

II. METHODS AND MATERIALS.

The subjects, ages 19 to 27, were US Army enlisted men who volunteered. Before testing, thorough vision and eye examinations, including slitlamp inspection of their corneas, were given to all the men. Each man had 20/20 visual acuity.

The men received either a drop or a spray of 0.1% or 0.25% CS in water with 0.5% polysorbate 20 in the right eye; the left eye served as a control.

In the group that received drops, five men got 0.1% CS and five got 0.25% CS. One drop (0.025 ml) was dispensed from an eyedropper onto the superior conjunctiva as the subject held his head back and looked down. The left eye was then covered, and the subject was asked to identify 20/100 Snellen letters that were 20 feet away. Testing was done indoors where the ambient temperature was 75°F.

* Owens, E. J., Ferrell, J. F., Weimer, J. T., Ballard, T. A., Merkey, R. P., Olson, J. S., and Samuel, J. B. EATR 4379. Ocular, Cutaneous, and Intratracheal Toxicity of CS-Water Slurries with and without a Surfactant in Animals. December 1969. UNCLASSIFIED Report.

** Rengstorff, R. H., Sim, V. M., and Petrali, J. P. EATR 4378. CS in Water: Effects of Massive Doses Sprayed into the Eyes of Rabbits. December 1969. UNCLASSIFIED Report.

† Weigand, D. A., Mershon, M. M., and Cox, A. T. EATR 4380. The Cutaneous Irritant Reaction to Agent CS. II. Reaction to Certain Solutions and Slurries of CS at Moderate and High Environmental Temperatures in Human Subjects. December 1969. UNCLASSIFIED Report.

In the group that received the spray, four men got 0.1% CS and two got 0.25% CS. The spray came from a handcarried disperser filled with 1 quart of the slurry and pressurized with two nitrogen cartridges to about 230 psig. The men stood behind an 8 by 4 foot sheet of cardboard with their faces pressed against vinyl chloride sheeting in which there was a 2-inch circular opening exposing only the right eye and surrounding area. Cotton was inserted between the side of the nose and the plastic sheet to prevent the spray from running into the volunteer's nose and mouth. The men were told to call out the large letters on a chart located 30° to their right. While the men were thus diverted, the sprayer, which was 15 feet directly in front of the subjects, was activated for 2 seconds. After the spray struck the eye, the cardboard was removed, the left eye was covered, and the men were asked to read from another Snellen chart with letters ranging from 20/100 to 20/20 that was 20 feet away (see figures 1 and 2).

From 3 to 15 minutes after the men received the irritant, we photographed the eyes (figures 3 and 4), applied a wet fluorescein-impregnated paper strip to the contaminated eyes, and inspected the corneas under an ultraviolet lamp. Then the corneas were examined with a Bausch and Lomb slitlamp biomicroscope. We repeated slitlamp examinations on all men 24 hours later, on Group A 52 days later, and on Group B 8 days later. Corneal curvature measurements were also taken on the men in the spray test.

III. RESULTS.

A. Subjective Symptoms.

The men did not react for 1 to 5 seconds after the irritant came in contact with their eyes. Then each man squeezed his eyes shut and grimaced. When asked how the eye felt, almost everyone said it burned. They added that the feeling was worse than that caused by soap, shampoo, or any previous CS aerosol. Even when urged, they could not open their eyes. All were obviously in pain. They reacted by hanging their heads down, clenching their fists, squeezing their heads, and rubbing their hands. A few men said it hurt more at 30 seconds than it did at 10 to 15 seconds. Relief occurred spontaneously within 3 or 4 minutes and there was no pain after 10 minutes. None of the men reported any eye discomfort on any subsequent examination.

B. Conjunctiva.

Marked conjunctival injection and considerable tearing were apparent as soon as each man opened his eyes. The redness diminished after 10 minutes but some injection remained for about 30 minutes; 1 hour later, the eyes appeared normal.

C. Cornea.

1. Fluorescein and Slitlamp Examination.

No fluorescein staining of the cornea was seen with the ultraviolet lamp. Slitlamp examinations showed staining on one man. The stained area was a hairline vertical strip of



Figure 1. Volunteer (No. 5546) Closes Eye after Contact with 0.25% CS-Water. Spray lasted about 2 seconds; a 2-inch circular opening exposes only the right eye.



Figure 2. Effect on Eyes about 30 Seconds after Release of Spray. Volunteer has burning sensation in right eye and difficulty opening either eye.



Volunteer 6



Volunteer 7



Volunteer 8



Volunteer 9



Volunteer 10

**Figure 3. Effect on Right Eye 3 Minutes after
a Single Drop of 0.25% CS-Water**



Volunteer 1; concentration, 0.1%



Volunteer 2; concentration, 0.1%



Volunteer 4; concentration, 0.1%



Volunteer 5; concentration, 0.25%



Volunteer 6; concentration, 0.25%

**Figure 4. Effect on Right Eye 10 Minutes after Spray
from Device Containing CS-Water**

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superficial epithelium, about 4 mm long and less than 0.5 mm wide, located temporally a few millimeters from the limbus. The area did not stain 24 hours later and appeared normal. The other volunteers had no abnormalities that could be seen with the slitlamp. There was no evidence of edema or damage to the epithelium or stroma at 24 hours, 8 days (Group B), or 52 days (Group A).

2. Ophthalmometry.

Table I shows corneal curvature measurements before and 10 minutes after each man received a spray from the device. Individual measurements after the spray did not differ more than 0.25 diopter from the original measurements. The control eyes showed the same normal range of variation usually found on repeated measurements.

D. Vision Effects.

Table II shows the time that elapsed before the men could open their eyes and identify 20/100 letters after receiving one drop of the irritant.

Table III shows the time that elapsed before the men could open their eyes and identify 20/100 and 20/20 letters after receiving a spray of the irritant.

IV. DISCUSSION.

One man had superficial corneal staining from the spray device. We are not certain whether this was caused by the slurry or was the result of trauma, e.g., rubbing the eye or abrading from an eyelash or foreign material. None of the other men had this finding, and although we do not disregard this occurrence, we do consider it relatively insignificant since it disappeared without treatment within 24 hours.

There did not appear to be significant differences in visual effects from the two concentrations in either the eye drop or spray test. Both the 0.1% and 0.25% concentrations caused the men to close their eyes, and the time that elapsed before they could read Snellen letters was similar for both concentrations.

A comparison of CS aerosols and CS slurries shows that many men could keep their eyes open in aerosol concentrations of up to 2.7 mg/cu m,* but none of the men in this study could keep their eyes open after contact with the CS slurry. The duration of conjunctival injection was about the same in both tests. We cannot make comparisons of pain, or discomfort because the aerosol tests also affected the skin and respiratory tract. The slurries did, however, consistently cause intense ocular pain.

* Rengstorff, R. H. The Effects of the Riot-Control Agent CS on Visual Acuity. *Military Med.* 134, 3 (1969).

Table I. Corneal Curvature Changes after Spray on Right Eye from Device Containing CS in Water with 0.5% Polysorbate 20

Subject	CS	Eye	Before spray	After spray	Change
			horizontal/vertical	horizontal/vertical	horizontal/vertical
diopters					
1	0.1	R	43.87/44.37	43.87/44.25	0.00/-0.12
		L	44.25/44.62	44.25/44.50	0.00/-0.12
2	0.1	R	44.12/44.87	44.12/44.87	0.00/ 0.00
		L	44.50/44.87	44.37/44.75	-0.12/-0.12
3	0.1	R	44.12/44.75	44.25/44.62	+0.12/-0.12
		L	44.12/45.00	44.12/44.87	0.00/-0.12
4	0.1	R	44.00/44.25	44.00/44.25	0.00/ 0.00
		L	43.75/44.62	43.62/44.50	-0.12/-0.12
5	0.25	R	41.62/42.87	41.75/43.12	+0.12/+0.25
		L	42.37/43.25	42.50/43.25	+0.12/ 0.00
6	0.25	R	41.62/42.12	41.62/42.25	0.00/+0.12
		L	42.00/42.87	41.87/42.87	+0.12/ 0.00

Table II. Time before Subjects' Eyes Opened and Time before 20/100 Letters Could Be Identified after One Drop (0.025 ml) of CS in Water with 0.5% Polysorbate 20 in the Eye

Subject	CS	Time before subjects' eyes opened	Time after eye drop before 20/100 letters could be identified
		sec	sec
1	0.1	35	*
2	0.1	20	*
3	0.1	45	90
4	0.1	40	95
5	0.1	30	120
6	0.25	10	65
7	0.25	10	40
8	0.25	15	110
9	0.25	50	70
10	0.25	25	75

* Subject was not tested with Snellen chart.

Table III. Time before Subjects' Eyes Opened and Time before 20/100 and 20/20 Letters Could Be Identified after Spray from Device Containing CS in Water with 0.5% Polysorbate 20

Subject	CS	Time before subjects' eyes opened	Time before letters could be identified	
			20/100	20/20
1	0.1	*	30	35
2	0.1	*	42	90
3	0.1	65	90	110
4	0.1	50	82	97
5	0.25	57	65	82
6	0.25	67	105	137

* Subject could open eyes for brief periods immediately after the spray. Because of wind gusts, only a fine mist reached the eye instead of the direct spray which visibly wet the eye region of the other subjects.

V. CONCLUSION.

Concentrations of 0.1% and 0.25% CS in water with 0.5% polysorbate 20 that reach the eye in either a drop or a brief spray cause transient conjunctivitis but no corneal damage in man.

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13. ABSTRACT
 (U) This was a study of the effects of 0.1% and 0.25% o-chlorobenzylidene malononitrile (CS) in water with 0.5% polysorbate 20 when placed in the human eye. Each of the 16 subjects received one drop or a brief spray in one eye. They could not open their eyes for 10 to 67 seconds, and only after 35 to 135 seconds were they able to read 20/20 letters. The visual incapacitation appeared to be similar for both concentrations. Fluorescein staining of the cornea was assessed under ultraviolet light and with a slitlamp biomicroscope. It was concluded that concentrations of 0.1% and 0.25% CS in water with 0.5% polysorbate 20 that reach the eye in either a drop or a brief spray cause transient conjunctivitis but no corneal damage in man.

14. KEYWORDS

CS	Eyes	Cornea
Conjunctiva	Polysorbate 20	Humans
Visual acuity	Spray device	

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